UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PETROGRAPHY OF IGNEOUS ROCKS FROM AMLIA ISLAND, ALEUTIAN ISLAND ARC, ALASKA

by

Walter B. Friesen

OPEN FILE REPORT 82-302

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INTRODUCTION

This report presents the results of detailed microscopic examination of of igneous rock thin sections from Amlia Island of the Aleutian chain (Fig. 1), and interpretations of those data. The rocks were collected in July, 1979, as part of a larger study of island arc, forearc, and trench sedimentation and tectonics of the Amlia Corridor of the Aleutian Island Arc (Hein and McLean, 1980; McLean and others, 1981; Scholl and others, 1981; Vallier and others, 1981). These studies are designed to deduce the geologic evolution of the Aleutian Ridge by examination of the geophysical and lithologic records in a 200-km-wide corridor traversing the Aleutian Island Arc perpendicular to its axis from the Pacific Basin to the Bering Sea. Amlia Island (173°W) is included in this corridor.

Prior to the reconnaissance geology of McLean and others (1980), no geologic study of Amlia Island had been undertaken. The main thrust of the investigations in 1979 centered on sample-collection and recording of field observations and relations. Among the many samples collected that summer was a suite of forty-nine igneous rocks. A sub-suite of thirty-one samples was chosen from the forty-nine for chemical and other studies. Detailed microscopic thin section examinations of the forty-nine igneous rocks were undertaken and 500-point modal counts were performed on the thirty-one selected for chemistry. The other eighteen sections were examined in detail and percentages of mineral phases, vesicles, and amygdules were estimated using the visual percentage estimation diagram of Terry and Chilingar (1955). Rock names for the thirty-one samples selected for chemistry were derived from the chemical classification of Irvine and Baragar (1971), whereas names for the eighteen remaining samples were derived from petrographic criteria. The samples in this study were also analyzed by X-ray diffraction technique which aided in the identification of mineral phases in thin section.

GEOLOGIC SETTING

The Aleutian Ridge represents a typical ensimatic volcanic arc which is mostly submerged. The Aleutian Islands represent peaks on a generally flat-topped structure that is 2,200 km long and 200-250 km wide. Amlia Island is one of these "mountain peaks" of the Aleutian Ridge. It is near the east end of the Andreanof Island group, adjacent to Atka Island. The island is 72 km long in an east-west orientation, about 8 km wide at its maximum, and its central ridge reaches a maximum elevation of about 600 m. The topography of the island is rugged and its coastline is characterized by many seacliffs, bays, and coves. It is barren except for low summertime tundra vegetation. Although there is no active volcanism on Amlia, it is evident that volcanism was responsible for its construction. The rocks of Amlia are tilted generally ten to fifteen degrees to the south, allowing exposure of a partial stratigraphic section. Weak folding and abundant faulting are evident in the volcanic pile, and the rocks have been altered by diagenesis and low grade metamorphism. The igneous rocks range in composition from basalt through rhyolite, and the sedimentary rocks represent first cycle erosion products from a nearby volcanic landmass.

The processes which formed Amlia Island are thought to have begun in

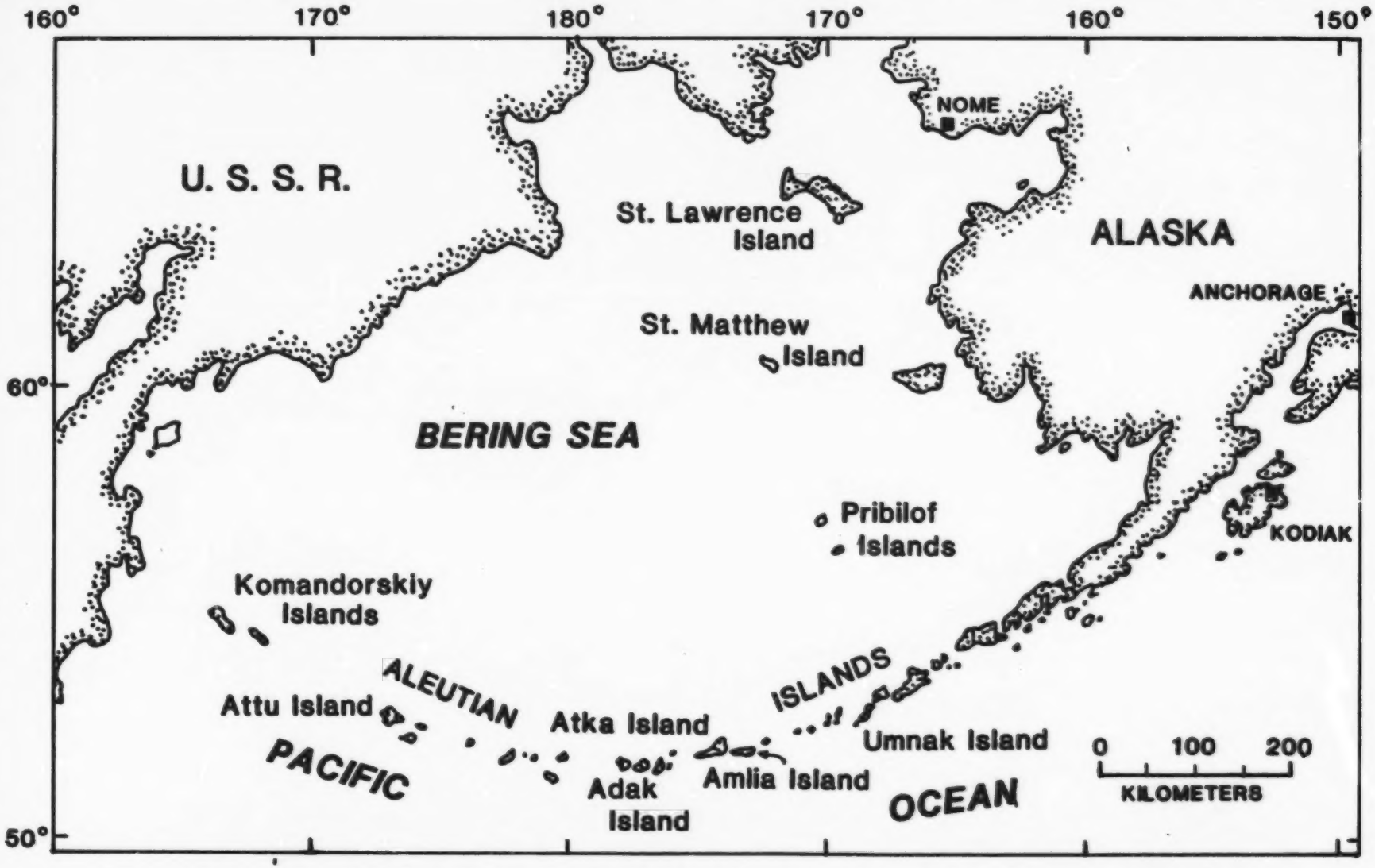

Fig. 1. Index map of the north Pacific showing the location of Amlia Island in the Aleutian Chain. (Courtesy H. McLean)

Eocene time and continued into the Neogene (McLean and others, 1981). Extrusive volcanism began the construction and intrusive activity, tectonism, and erosion/deposition cycles augmented it. The volcanic rocks of Amlia Island apparently include both submarine and subaerial, consisting of flow breccias and massive, columnar and pillowed lava flows. The intrusive rocks consist of dikes, sills, and other hypabyssal intrusions. Figure 2 is a geologic sketch map of Amlia Island, with sample localities indicated.

PETROGRAPHY

Extrusive rocks of Amlia Island include basalt, basaltic andesite, andesite, dacite, and rhyolite. The intrusive rocks include gabbro, basalt, basaltic andesite, tonalite, and dacite. The extrusive rocks are generally quite glassy, displaying much incipient crystallization and are plagioclase/pyroxene phyric. The intrusive rocks frequently have intersertal glass in the groundmass but are otherwise plagioclase/pyroxene phyric granular. All the rocks display incipient to thorough propylitic alteration.* The mineralogy of the rocks is rather constant. The main variations are in the proportion of minerals to one another rather than differences in mineralogy. Table 1 summarizes the primary mineralogy by rock type. All samples contain plagioclase, clinopyroxene, orthopyroxene, and Fe-Ti oxides. Primary phases which occur in only rare samples are amphibole, apatite, potash feldspar, olivine, and quartz. Most of the rocks contain phenocrysts of plagioclase, clinopyroxene, and orthopyroxene. Rocks exclusive of basalt, gabbro, and tonalite contain phenocrysts of potash feldspar and all rocks exclusive of basaltic andesite contain Fe-Ti oxide (ore) phenocrysts. Only tonalite contains primary amphibole. Primary groundmass phases include plagioclase, clinopyroxene, orthopyroxene, quartz, potash feldspar, ore, olivine, and apatite. Potash feldspar, as a groundmass phase, is found only in rhyolite and basaltic andesite. Apatite is an accessory phase in all rock types exclusive of basaltic andesite and tonalite. Olivine (totally replaced by calcite) is found only in isolated samples. Textures in the Amlia rocks are felted, hyaloophitic, hyalopilitic, hypidiomorphic granular, intergranular, intersertal, microlitic, subophitic, and subtrachytic. All the volcanic rocks are porphyritic with most samples having groundmass textures from intergranular to intersertal, tending towards hyalopilitic. Deformational textures are absent in the rocks and phase changes are restricted to simple devitrification and recrystallization. Vesicle percentages in the Amlia volcanics are rather low; most samples contain less than ten percent. Maximum vesiculation, determined by modal analyses, is thirty percent in a basalt sample taken from the north coast of the island.

Metasomatic alteration of the Amlia rocks is most evident in the groundmass glasses. In most instances, these glasses have totally devitrified to zeolites and clay minerals. Microlites and skeletal crystals of amphibole(?), analcite(?), biotite(?), celadonite, chlorite, chlorophaeite**,

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* refers to hydrothermal alteration resulting in the formation of calcite, chlorite, epidote, and similar low-grade metamorphic minerals.

** Green to greenish-brown smectite mineral of variable Fe and Mg contents, with composition between nontronite and saponite.

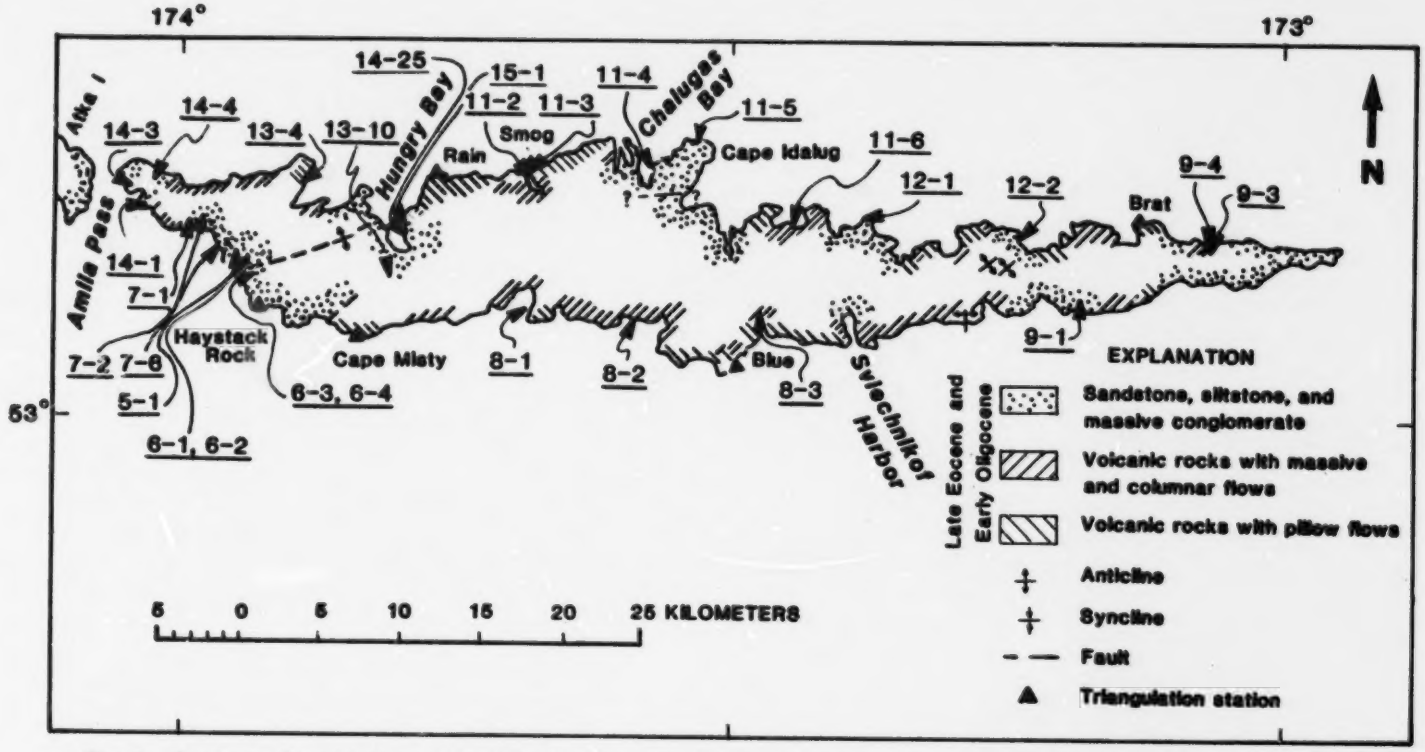

Fig. 2. Geologic Sketch Map of Amlia Island showing igneous rock sample localities. (Courtesy H. McLean)

Table 1. Summary of primary mineralogy, igneous rocks of Amlia Island.

Extrusive Rocks

Rock Type	Phenocrysts						Groundmass								
	Clino-pyroxene	Fe-Ti oxide ore	Olivine	Ortho-pyroxene	Plagio-clase	Potash Feldspar	Apatite	Clino-pyroxene	Fe-Ti oxide ore	Glass	Olivine	Ortho-pyroxene	Plagio-clase	Potash Feldspar	Quartz
Basalt	x	x	x	x	x		x	x	x	x	x	x	x		x
Basaltic Andesite	x			x	x			x	x	x			x		x
Andesite	x	x		x	x	x	x	x	x	x		x	x		x
Dacite	x	x		x	x	x	x	x	x	x		x	x		x
Rhyolite	x	x		x	x	x	x	x	x	x		x	x	x	x

Intrusive Rocks

Rock Type	Phenocrysts						Groundmass								
	Amphi-bole	Clino-pyroxene	Fe-Ti oxide ore	Ortho-pyroxene	Plagio-clase	Potash Feldspar	Apatite	Biotite?	Clino-pyroxene	Fe-Ti oxide ore	Glass	Ortho-pyroxene	Plagio-clase	Potash Feldspar	Quartz
Basalt		x			x				x	x	x		x		x
Basaltic Andesite		x		x	x	x			x	x	x	x	x	x	x
Dacite		x	x		x		x		x	x	x	x	x		x
Gabbro		x	x	x	x		x	x	x	x	x	x	x		x
Tonalite	x	x	x	x	x				x	x		x	x		x

and other smectites, epidote(?), goethite(?), hematite, magnetite(?), pumpellyite, and zeolites are visible in various associations in almost all of the glasses. Propylitic or secondary mineral phases observed in the Amlia igneous rocks include amphibole, analcite, biotite(?), calcite, celadonite, chlorite, chlorophaeite and other smectites, epidote, goethite, hematite, kaolinite, leucoxene, prehnite(?), pumpellyite, sericite(?), and natrolite and other zeolites (Table 2). Clinopyroxene is replaced by amphibole, chlorite, smectite(?), pumpellyite(?), and chlorophaeite. Olivine is replaced by calcite, smectite, and chlorophaeite. Ore phases are replaced by hematite and leucoxene. Potash feldspar is replaced by kaolinite, pumpellyite, sericite(?), and zeolites. Orthopyroxene is replaced by calcite, chlorite, hematite, and chlorophaeite and other smectites. Plagioclase is replaced by epidote, kaolinite, prehnite(?), pumpellyite, sericite(?), smectite, and zeolites.

Deuteric activity in the form of vesicle fillings and cross-cutting veinlets is abundant in many of the rocks, particularly the extrusive rocks (Tables 3 and 4). Vesicle fillings in basalts include calcite, chlorophaeite and other smectites, quartz, natrolite(?), and other zeolites. Chlorophaeite, quartz, pumpellyite(?) and zeolite amygdules were seen in basaltic andesites. Quartz, smectite, and zeolite amygdules occur in andesites. The dacites contain only smectite amygdules, whereas the rhyolites have amygdules of chlorophaeite, quartz, and zeolites. Deuteric minerals deposited in cross-cutting veinlets cover an even larger, but similar, range of mineral phases. Veinlets containing analcite, calcite, goethite, quartz, smectite, and zeolites were observed in basalts. Andesites displayed veinlets containing hematite, manganic oxide(?) and quartz. Dacites have veinlets composed of chlorophaeite and other smectites, goethite, hematite, kaolinite, prehnite(?), quartz, natrolite(?) and other zeolites. Rhyolites showed veinlets made up of epidote(?), hematite, pumpellyite, and quartz. Table 5 summarizes all petrographic data.

PETROLOGY AND DISCUSSION

Major, minor, and trace element chemistry of selected igneous rock samples from Amlia Island are presented and discussed by McLean and others, (1981), and Vallier and others, (1981; in preparation). In this study, an attempt is made to document the distribution and alteration of primary phases in the igneous rocks of Amlia Island through space and time, and to suggest mechanisms for the origin and subsequent metamorphism of these phases.

The rocks have calc-alkaline/tholeiitic mineral assemblages when reconstructed by chemical and normative techniques (Vallier and others, 1981). The range and distribution of the component phases are rather remarkable, however, in that mafic minerals like clinopyroxene, are often abundant in the rhyolites, and minerals such as quartz are often abundant even in basalt. Both phenocryst and groundmass plagioclase compositions determined by the optical method of Michel-Levy, have high anorthite content characteristic of plagioclase of the tholeiitic suite. Even higher anorthite contents were obtained by microprobe analysis. Table 6 summarizes microprobe analyses of plagioclase in selected Amlia samples.

Potash feldspar was identified by the presence of solitary Carlsbad twinning and axial angles (2E) of less than 40°. They are probably potassium-

Table 2. Mineral phase replacement, igneous rocks of Amlia Island

Rock Type	Amphibole? replaces	Analcite? replaces	Biotite? replaces	Calcite replaces	Celadonite replaces	Chlorite replaces	Chlorophaeite replaces	Epidote replaces	Hematite replaces	Kaolinite replaces	Leucosene replaces	Pumpellyite replaces	Sericite? replaces	Smectite (alkali) replaces	Zeolites (undiff.) replaces
					Extrusive Rocks										
Basalt	cpx Glass	Glass plag		Olivine opx		Glass opx	Glass Olivine opx	Glass plag	Fe-Ti oxide (ore)	plag	Fe-Ti oxide (ore)	Glass plag	plag	cpx Glass opx plag	Glass plag
Basaltic Andesite			Glass	cpx		Glass opx	cpx Glass opx		Fe-Ti oxide (ore)		Fe-Ti oxide (ore)	cpx Glass plag	plag	Glass opx	Glass
Andesite	cpx Glass			opx	Glass	Glass opx	Glass opx	plag	Glass opx	plag		Glass plag	plag	cpx Glass opx plag	Glass plag
Dacite							cpx Glass		Fe-Ti oxide (ore)	plag	Fe-Ti oxide (ore)	Glass	plag	Glass opx	Glass
Rhyolite					Glass		cpx Glass opx	plag	cpx Fe-Ti oxide (ore) Glass opx	plag	Fe-Ti oxide (ore)	cpx Glass opx plag	plag	Glass opx	Glass plag

Table 2. (Continued).

Rock Type	Amphibole replaces	Biotite? replaces	Calcite replaces	Chlorite replaces	Chlorophaeite replaces	Hematite replaces	Kaolinite replaces	Leucoxene replaces	Prehnite? replaces	Pumpellyite replaces	Sericite? replaces	Smectite (alkali replaces)	Zeolites (Undif) replaces
						Intrusive Rocks							
Basalt					Glass		plag				plag	Glass plag	
Basaltic Andesite		Glass	opx	Glass opx	opx			Fe-Ti oxide (ore)		Glass plag cpx	plag	Glass	Glass
Dacite					Glass opx	Fe-Ti oxide (ore)		Fe-Ti oxide (ore)	plag		plag		
Gabbro	cpx			cpx opx		Fe-Ti oxide (ore)	plag	Fe-Ti oxide (ore)			plag	cpx Glass opx plag	Glass
Tonalite					opx		plag	Fe-Ti oxide (ore)		plag	plag		plag

Table 3. Deuteric mineral veinlet distribution, extrusive rocks of Amlia Island.

Rock Type	Mineralogy													
	Analcite	Calcite	Chloro-phaeite	Epidote?	Goethite	Hematite	Kaolinite	Manganic Oxide?	Natro-lite?	Preh-nite?	Pumpe-llyite	Quartz	Smectite (alkali)	Zeolites (undiff.)
Basalt	x	x			x							x	x	x
Andesite						x		x				x		
Dacite			x		x		x		x	x		x	x	x
Rhyolite				x		x		x			x	x		

Table 4. Mineralogy and distribution of amygdules in the extrusive rocks of Amlia Island.

Rock Type	Mineralogy							
	Calcite	Chloro-phaeite	Chlorite	Natro-lite?	Pumpel-lyite?	Quartz	Smectite	Zeolites (undiff)
Basalt	x	x	x	x		x	x	x
Basaltic andesite		x			x	x		x
Andesite						x	x	x
Dacite							x	
Rhyolite		x				x		x

Table 5. Thin Section Petrography, Igneous Rocks of Aulis Island. Components are given in volume percent. Phenocryst-plus groundmass components represent primary minerals. Alteration component percentages are from petrographic analyses. Point counts, 500 per thin section.

No.	Sample Number	Rock Type	Texture	Phenocryst [2] Component	Percent	Groundmass Component	Percent	Vesicles/Amygdules Filling	Percent	Remarks
1.	779-5-1	Basaltic [1] andesite	Intersertal	Plagioclase	11	Plagioclase	39	Quartz	7	Dike, ~2m thick, 2m coast of Island. Plagioclase is glomeroporphyric with light brown to neutral, altered cpx and totally altered opx(?), and is strongly zoned; glass is totally altered.
				Orthopyroxene(?)	1	Glass	34			
				Clinopyroxene	<1	Clinopyroxene	19			
						Ore	6			
						Orthopyroxene(?)	1			
				Total [3]		99+				
2.	779-6-1A	Basalt	Intersertal	Plagioclase	30	Plagioclase	22	Chlorophaeite	10	Flow rock clast in volcanic breccia. 2m coast of Island. Plagioclase is unit phyric and is highly sevitized along strong cracks; cpx is fresh, neutral in color, and unit phyric; opx(?) is totally altered and unit phyric; glass is totally altered.
				Orthopyroxene(?)	8	Clinopyroxene	16	Calcite		
				Clinopyroxene	1	Glass	8	Zeolites		
						Ore	6			
						Orthopyroxene(?)	1			
				Total [3]		100				
3.	779-6-1B	Basalt	Intergranular to intersertal	Plagioclase	35	Plagioclase	15	Zeolites	20	Clast in volcanic breccia described above. Plagioclase is unit phyric, strongly zoned and zeolitized along strong cracks; cpx is unit phyric, neutral in color, with a yellowish tinge, and shows evidence of resorption; opx (?) is unit phyric and totally altered; glass is totally altered.
				Clinopyroxene	1	Clinopyroxene	10	Chlorite		
				Orthopyroxene(?)	<1	Glass	10	(80% are empty)		
						Ore	8			
				Total [3]		99+				
4.	779-6-2	Andesite [1]	Hyalopilitic	Plagioclase	11	Glass	36	None		Pillow lava, individual pillows ~1-2m in dia., 2m coast of Island. Plagioclase is glomerophyric with itself, orthoclase(?), cpx, opx(?), and ore, is rarely unit phyric, is kaolinitized and sassuritized; orthoclase(?) is glomerophyric, and altered; cpx is fresh, yellowish to greenish-neutral in color, is usually glomerophyric but also rarely unit phyric; opx(?) is glomerophyric and totally altered; ore is microglomerophyric; matrix phases are largely microlitic, but is highly altered quartz-charged glass.
				Orthoclase(?)	3	Plagioclase	19			
				Clinopyroxene	2	Quartz	19			
				Ore	1	Clinopyroxene	6			
				Orthopyroxene(?)	<1	Ore	2			
				Total [3]		99+				
5.	779-6-2C	Andesite [1]	Hyalopilitic	Plagioclase	19	Glass	61	Zeolites	9(?)	Massive flow interbedded with coarse sandstone, 2m coast of Island. Plagioclase is glomerophyric with fresh, pale smoky yellow cpx and totally altered opx(?); glass is totally altered.
				Clinopyroxene	3	Plagioclase	21	Quartz		
				Orthopyroxene(?)	1	Clinopyroxene	9	(may be part of		
						Ore	3	the matrix)		
						Orthopyroxene(?)	2			
				Total [3]		99+				

No.	Sample Number	Phenocryst [2] Component	Percent	Groundmass Component	Percent	Alteration [4] Alteration Component	Primary Component	Percent
1.	779-5-1	Plagioclase	11	Plagioclase	42	Smectite	Glass	28
		Orthopyroxene(?)	1	Glass	36	Chlorite	Glass, cpx(?)	2
		Clinopyroxene	<1	Clinopyroxene	11	Calcite	Orthopyroxene(?)	<1
				Ore	7			
				Orthopyroxene(?)	1			
		Total		100+				
2.	779-6-1A	Plagioclase	33	Plagioclase	24	Zeolites	Glass, plag.	20
		Orthopyroxene(?)	9	Clinopyroxene	16	Chlorophaeite	cpx(?), glass	6
		Clinopyroxene	1	Glass	9	Calcite	Orthopyroxene(?)	3
				Ore	7			
				Orthopyroxene(?)	1			
		Total		100				
3.	779-6-1B	Plagioclase	44	Plagioclase	19	Zeolites	Glass, plag.	35
		Clinopyroxene	1	Clinopyroxene	13	Chlorophaeite	cpx(?), glass	10
		Orthopyroxene(?)	<1	Glass	13			
				Ore	10			
		Total		100+				
4.	779-6-2					Chlorite	Glass, cpx(?)	6
						Zeolites	Feldspars, glass	6
						Smectite	Glass, cpx(?)	1
						Kaolinite	Feldspars	<1
						Epidote	Feldspars	<1
						Pumpellyite(?)	Feldspars	<1
						Calcite	Orthopyroxene(?)	<1
						Hematite	Glass	<1
5.	779-6-2C	Plagioclase	19	Glass	61	Smectite	Glass, cpx(?)	75
		Clinopyroxene	3	Plagioclase	21	Zeolites	Glass, plag.	5(?)
		Orthopyroxene(?)	1	Clinopyroxene	9	Quartz	(dentoric)	4
				Ore	3	Sericite(?)	Plagioclase	2
				Orthopyroxene(?)	2			
		Total		100				

1)Chemical classification of Irvine and Baragar (1971). Remainder are classified petrographically.
2)Phenocrysts + groundmass + vesicles = 100%. 3)Normalized percentages where vesicle percentages are >1. 4)Total alteration of all phases.

*distinguishes single phenocrysts from clustered phenocrysts.

Table 4.cont.

6. 779-6-c	Basaltic andesite[1]	Intersertal	Plagioclase	12	Plagioclase	31	Zeolites	2	Plagioclase	12	Plagioclase	32	Chlorite	Glass,cpx(?)	12	Dike, about 4m wide, SW coast of island. Plagioclase and orthoclase(?) are unit phyric and also often glomeroporphyric with each other, and also with very fresh, pale cloudy yellow cpx and totally altered opx(?); glass is totally altered.
			Clinopyroxene	9	Orthoclase(?)	15			Clinopyroxene	9	Orthoclase(?)	16	Zeolites	Glass	7	
			Orthoclase(?)	3	Glass	13			Orthoclase(?)	3	Glass	13	Pumpellyite(?)	Pla.,glass,cpx	2	
			Orthopyroxene(?)	<1	Clinopyroxene	7			Orthopyroxene(?)	<1	Clinopyroxene	7	Leucoxene	Ore	2	
					Ore	6					Ore	6	Biotite(?)	Glass	1	
					Quartz	1					Quartz	1	Sericite(?)	Plagioclase	1	
			Total [2]		Orthopyroxene(?)	<1			Total		Orthopyroxene(?)	<1				
					99+							99+				
7. 779-7-1	Basalt	Hyalopilitic	Plagioclase	15	Glass	25	Zeolites	29	Plagioclase	19	Glass	30	Smectite	Glass	25	Pillow lava interior, extreme SW coast of island. Plagioclase is glomeroporphyric with fresh, neutral-colored cpx, and includes glass; opx(?) is unit phyric and totally altered; glass is totally altered.
			Clinopyroxene	5	Plagioclase	13			Clinopyroxene	8	Plagioclase	15	Zeolites	Glass, Plag.	15	
			Orthopyroxene(?)	3	Clinopyroxene	11			Orthopyroxene(?)	4	Clinopyroxene	14	Chlorite	Orthopyroxene(?)	4	
					Ore	6					Ore	8	Sericite(?)	Plagioclase	1	
			Total [2]		Orthopyroxene(?)	1			Total		Orthopyroxene(?)	1				
					100							100				
8. 779-7-4A	Basalt	Intersertal	Plagioclase	30	Plagioclase	21	Calcite	1	Plagioclase	33	Plagioclase	21	Smectite	Cpx(?), glass	20	Pillow lava, extreme SW coast of island. Plagioclase is glomeroporphyric with itself and with cpx, and includes glass; cpx(?) is glomeroporphyric with itself or with cpx only, and is totally altered to calcite rimmed with smectite, cpx is neutral in color and shows evidence of resorption; glass is totally altered; rock texture is locally hyalopilitic (around vesicles).
			Orthopyroxene(?)	5	Clinopyroxene	20			Orthopyroxene(?)	5	Clinopyroxene	29	Calcite	Orthopyroxene(?)	7	
			Clinopyroxene	3	Glass	15			Clinopyroxene	3	Glass	15				
					Ore	6					Ore	6				
			Total [2]		Orthopyroxene(?)	<1			Total		Orthopyroxene(?)	<1				
					100+							99+				
9. 779-7-4B	Basalt [1]	Subophitic to Intersertal	Plagioclase	27	Glass	27	Smectite	2	Plagioclase	28	Glass	28	Smectite	Glass,cpx(?)	31	Top of pillowed lava flow, same locality as above. Plagioclase is mostly unit phyric, is strongly zoned and complexly twinned; some of it is glomeroporphyric with cpx and includes glass; cpx is either unit phyric or is glomeroporphyric with totally altered cpx(?), rare microcensryots of ore are glomeroporphyric with each other only and show evidence of resorption; glass is totally altered.
			Orthopyroxene(?)	6	Plagioclase	16			Orthopyroxene(?)	4	Plagioclase	16	Calcite	Orthopyroxene(?)	<1	
			Clinopyroxene	1	Clinopyroxene	16			Clinopyroxene	1	Clinopyroxene	16	Sericite(?)	Plagioclase	<1	
					Ore	7					Ore	7				
			Total [2]		Orthopyroxene(?)	<1			Total		Orthopyroxene(?)	<1				
					100+							100+				
10. 779-8-1A	Basalt [1]	Hyalopilitic	Plagioclase	2	Glass	52	Zeolites	1	Plagioclase	2	Glass	53	Zeolites	Glass	33	Massive thick flow with columnar jointing, south coast of island along east side of first bay west of Sharp Point. Plagioclase and orthoclase(?) are glomeroporphyric with each other and with the other phyric phases as well; cpx is neutral in color and quite fresh; opx is totally altered, glass is totally altered; apatite observed in the matrix.
			Clinopyroxene	2	Quartz	18			Clinopyroxene	2	Quartz	18	Smectite	Glass	23	
			Orthoclase(?)	<1	Plagioclase	15			Orthoclase(?)	<1	Plagioclase	15	Sericite(?)	Plagioclase	1	
			Ore	<1	Clinopyroxene	4			Ore	<1	Clinopyroxene	4	Zeolite	Plagioclase	<1	
					Ore	3					Ore	3	Pumpellyite(?)	Glass	<1	
					Apatite	<1					Apatite	<1				
			Total [2]		Orthopyroxene(?)	<1			Total		Orthopyroxene(?)	<1				
					99+							100+				

Table 9.cont.

11. 779-0-10	Andesite[7]	Hyalopilitic	Plagioclase	6	Glass	59	Zeolites	2	Plagioclase	6	Glass	61	Zeolites	Glass	50	Clast in volcanic breccia, same locality as above. Plagioclase and rare orthoclase(?) are omit phyric and also infrequently glomerophyric with each other and with other phyric phases; cpx, along with other phyric phases, is frequently euhedral, neutral in color, and often includes ore and apatite; opx is almost totally altered; glass is to extensively altered and crowded with spherulitic microlites.
			Clinopyroxene	3	Plagioclase	12			Clinopyroxene	3	Plagioclase	12	Smectite	Glass, opx	10	
			Orthopyroxene	<1	Clinopyroxene	12			Orthopyroxene	<1	Clinopyroxene	12	Sericite(?)	Plagioclase	<1	
			Orthoclase(?)	<1	Orthopyroxene	5					Orthopyroxene	5				
			Ore	<1	Ore	1					Ore	1				
			Total 3)		99+				Total		99+					
12. 779-0-28	Basalite[7]	Porphyritic granular	Plagioclase	8	Plagioclase	79	Quartz (lining)	<1								
			Orthopyroxene(?)	2	Quartz	10										
			Ore	2	Orthopyroxene(?)	3							Chlorophaeite	Orthopyroxene(?)	5	Massive sill, 3 m thick, south side of island in first bay east of Sharp Point. Highly altered plagioclase is glomerophyric with totally altered opx(?), fresh subequal, yellowish cpx, and microphyric, euhedral ore; rare prisms of greenish-yellowish amphibole are associated with the opx(?), euhedral quartz is abundant in the matrix.
			Clinopyroxene	1	Ore	2							Kaolinite	Plagioclase	2	
			Amphibole	1	Clinopyroxene	1							Pumpellyite(?)	Plagioclase	2	
			Total 3)		99+								Zeolites	Plagioclase	<1	
													Sericite(?)	Plagioclase	<1	
13. 779-0-29	Basalite[7]	Porphyritic granular	Plagioclase	19	Plagioclase	56	Rarely quartz, usually empty	4	Plagioclase	20	Plagioclase	50	Kaolinite	Plagioclase	5	Massive sill, same as 0-28. Plagioclase is glomerophyric with itself or with fresh, neutral-colored cpx, totally altered opx(?), and rarely with euhedral ore; quartz is abundant interstitially in the groundmass.
			Clinopyroxene	1	Quartz	14			Clinopyroxene	1	Quartz	15	Chlorophaeite	Orthopyroxene(?)	4	
			Orthopyroxene(?)	1	Ore	3			Orthopyroxene(?)	1	Ore	3	Sericite(?)	Plagioclase	<1	
			Ore	<1	Orthopyroxene(?)	2			Ore	<1	Orthopyroxene(?)	3	Zeolites	Plagioclase	<1	
					Clinopyroxene	<1					Clinopyroxene	<1				
			Total 2)		100+				Total		100+					
14. 779-0-30	Basalite[7]	Porphyritic granular	Plagioclase	26	Plagioclase	64	Quartz	<1								
			Clinopyroxene	3	Quartz	23	Zeolites									
			Orthopyroxene(?)	1	Ore	3										
					Clinopyroxene	3										
			Total 2)		Orthopyroxene(?)	1							Pumpellyite(?)	Plagioclase	6	Massive sill, same as 0-28. Kaolinitized plagioclase is glomerophyric with fresh, skeletal, neutral-colored cpx and totally altered opx(?); opaques display ten distinct grain sizes; matrix texture is microlitic in part; quartz occurs as tiny blebs disseminated abundantly through the groundmass.
					100								Kaolinite	Plagioclase	5	
													Chlorophaeite	Orthopyroxene(?)	2	
													Zeolites	Plagioclase	1	
													Sericite(?)	Plagioclase	<1	
													Leucoxene	Ore	<1	
15. 779-0-31	Andesite[7]	Intergranular	Plagioclase	12	Plagioclase	42	None									
			Clinopyroxene	6	Glass	21							Smectite	Glass,opx(?)	10	Massive flow, lower part of first flow from bay east of Sharp Point. Plagioclase is glomerophyric with ore and almost colorless cpx, and is highly zoned and kaolinitized; opx(?) is totally altered and almost curiously glomeroporphyric with cpx; matrix phases are almost microlitic and the ore phases range from dendritic to granular in ten distinct grain sizes; matrix opx(?) is totally altered and difficult to distinguish from totally altered glass; quartz appears as blebs in the glass.
			Orthopyroxene(?)	3	Quartz	8							Kaolinite	Plagioclase	10	
			Ore	<1	Clinopyroxene	6							Zeolites	Glass	5	
					Ore	3							Sericite(?)	Plagioclase	1	
					Orthopyroxene(?)	<1							Smectite	Glass	<1	
			Total 3)		99+								Pumpellyite(?)	(Unstable)	<1	

Table 1.cont.

16. 779-9-3B	Andesite(?)	Intergranular	Plagioclase	5	Plagioclase	58	None						Smectite	Glass, opx(?)	25	Massive flow, lower part of second flow, same locality as 9-3A. Plagioclase is glomerophyric with all other phyric phases; cpx is very fresh, nearly colorless, and often unit phyric, including macrophyric ore; opx(?) is highly to totally altered,faintly pleochroic from pinkish to greenish in unaltered parts, usually glomerophyric, rarely unit phyric,and then rimmed with cpx; glass and matrix opx(?) are totally altered and difficult to distinguish.
			Clinopyroxene	3	Orthopyroxene(?)	25							Zeolites	Plagioclase	2	
			Orthopyroxene	2	Ore	10							Hematite(?)	Plagioclase	<1	
			Ore	1	Glass	2										
					Clinopyroxene	1										
			Total 2)		Quartz	1										
					100											
17. 779-9-3C	Basaltic andesite 1)	Intergranular	Plagioclase	3	Plagioclase	66	Pumpellyite(?)	<1	Plagioclase	3	Plagioclase	67	Hematite	Ore	12	Massive flow, upper part of second flow, same locality as 9-3A. Plagioclase is unit phyric and also glomerophyric with almost colorless, internally deformed, fresh cpx; matrix cpx is the freshest phase, but matrix ore is totally altered to red, translucent hematite.
			Clinopyroxene	<1	Clinopyroxene	29	Zeolites		Clinopyroxene	<1	Clinopyroxene	19	Chlorite	Glass	11	
					Glass	19					Glass	19	Pumpellyite	Glass,plag.	8	
					Ore	12					Ore	12	Metrolite(?)	(Deuteric)	<1	
			Total 2)		99+				Total		100		Hematite(?)	Plagioclase	<1	
18. 779-9-4A	Basaltic andesite 1)	Intersertal	Plagioclase	7	Plagioclase	35	Zeolites	17	Plagioclase	8	Plagioclase	31	Chlorophaeite	Cpx(?),cpx,glass	96	Massive, columnar flow just west of Ocean Point, south side of island. Plagioclase is glomerophyric with itself ,less frequently with cpx and opx(?); cpx is usually unit phyric and neutral in color; opx(?) is usually glomerophyric with plagioclase, totally altered and quite rare, matrix phases' grain sizes and textures vary markedly within the section; glass is totally altered and bears minor quarts.
			Clinopyroxene	1	Glass	21	Chlorophaeite		Clinopyroxene	1	Glass	25	Zeolites	Glass	1	
			Orthopyroxene(?)	<1	Clinopyroxene	19			Orthopyroxene(?)	<1	Clinopyroxene	23	Hematite(?)	Plagioclase	<1	
					Ore	6					Ore	7	Hematite	Ore	<1	
			Total 2)		Quartz	3					Quartz	6				
					100+				Total		99+					
19. 779-9-4B	Basalt ???	Intersertal	Clinopyroxene	3	Plagioclase	48	Smectite	<1	Clinopyroxene	2	Plagioclase	49	Smectite	Glass, plag.	22	Dike, same location as 9-4A. Clinopyroxene is microphyric, neutral in color, strongly center-zoned, and often partially enclosed matrix phases; matrix plagioclase is reticulated with smectite-filled fractures, ore phases are frequently skeletal; glass is totally altered and bears minor quarts.
					Glass	22					Glass	23				
					Clinopyroxene	17					Clinopyroxene	17				
					Ore	6					Ore	6				
			Total 2)		Quartz	3					Quartz	3				
					99+				Total		100					
20. 779-9-5A	Basalt (?)	Spherulitic	Plagioclase	5	Glass	36	None						Smectite	Glass	5	Glassy selvage of pillow lava, first bay west of East Head on north side of island. Plagioclase is glomerophyric with all other phyric phases, is strongly zoned, and remarkably fresh; cpx is neutral in color and shows evidence of resorption; opx is remarkably fresh and faintly pleochroic from pinkish to greenish; ore is glomerophyric with itself as well as all other phyric phases; glass is mahogany brown in color and only partially altered, displaying numerous perlitic fractures.
			Orthopyroxene	2	Plagioclase	35							Zeolites	Glass,deuter.	2	
			Ore	2	Clinopyroxene	25							Metrolite(?)	(Deuteric)	2	
			Clinopyroxene	1	Orthopyroxene	2							Goethite(?)	(Deuteric)	3	
			Total 2)		Ore	2										
					100											

Table 5-cont.

21. 770-9-20	Dacite [7]	Spherulitic	Plagioclase	6	Glass	55	Zeolites	3	Plagioclase	4	Glass	87	Zeolites	Glass	95	Pillow lava interior, same locality as 9-18. Plagioclase is glomerophyric mostly with itself, less frequently with cpx, opx, and ore; cpx is central in color and glomerophyric with all other phyric phases; opx is quite fresh and is faintly pleochroic from pinkish to greenish; matrix ore displays three distinct grain sizes; quartz appears as blebs in glass which is charged with hematite dust.
			Clinopyroxene	1	Plagioclase	58	(Totalcite)		Clinopyroxene	1	Plagioclase	99	Hematite	Glass	5	
			Orthopyroxene	<1	Clinopyroxene	9	Quartz	<1	Orthopyroxene	<1	Clinopyroxene	9	Quartz	Glass,opx	2	
					Quartz	9	Zeolites				Quartz	9	Goethite	(Dentaria)	<1	
			Total 2)		Ore	1			Total		Ore	1				
					100+						100+					
22. 770-9-18	Rhyolite [7]	Intergranular	Orthoclase (?)	6	Glass	60	None						Pumpellyite	Glass, opx	9	Pillow lava interior, near locality 9-18. Orthoclase(?) and plagioclase are both unit phyric and glomerophyric with cpx, opx, and ore; cpx is yellowish and includes microphyric ore; opx is most often unit phyric and ranges from quite fresh to totally altered; matrix orthoclase(?) occurs as short laths, matrix ore and plagioclase display two distinct grain sizes and the ore is highly altered glass is totally altered.
			Plagioclase	9	Plagioclase	26							Zeolites	Glass	6	
			Clinopyroxene	1	Quartz	13							Hematite	Ore	<1	
			Orthopyroxene	<1	Clinopyroxene	6							Leucoxene	Ore	<1	
					Orthoclase(?)	6										
			Total 2)		Ore	5										
					100+											
23. 770-11-2	Andesite [7]	Hyalomorphic granular			Plagioclase	72	None						Zeolites	Plagioclase	11	Small hypabyssal pluton from unusual small bay west of Hwy Point, north side of island. Plagioclase is highly altered, and cut/replaced with fractures; cpx occurs as unit crystals or as clusters composed of ore, opx, and and rare apatite. It is peripherally replaced and includes microlites of apatite; ore phases are unusual in aspect.
					Clinopyroxene	16							Hematite	Cpx, opx	7	
					Orthopyroxene	7							Sericite(?)	Plagioclase	4	
					Ore	4							Amphibole	Cpx	<1	
					Apatite	<1										
			Total 2)		Quartz	<1										
					100											
24. 770-11-1	Basalt [7]	Intergranular	Plagioclase	11	Plagioclase	51	None						Hematite	Glass,opx(?),cpx	7	Pillow lava interior, near Hwy Point, north side of island. Plagioclase is unit phyric, strongly zoned, and includes totally altered glass, altered matrix ore, and fresh, neutral-colored matrix cpx; cpx glomerocrysts are glomerophyric with each other and also with totally altered opx(?), and often include matrix plagioclase and totally altered glass; matrix plagioclase is fresher than phyric plagioclase, and includes rare microlites of apatite; ore is chromian in aspect; all glass is totally altered.
			Clinopyroxene	1	Clinopyroxene	28							Chlorophaeite	Glass	6	
			Orthopyroxene(?)	1	Glass	6							Chlorite	Glass	6	
					Ore	3							Zeolite	Plagioclase	3	
					Quartz	3							Sericite(?)	Plagioclase	<1	
					Orthopyroxene(?)	2							Amphibole	Cpx	<1	
			Total 2)		Apatite	<1										
					100											

Table 4-cont.

26. 770-11-4A Basalt [7]	Intergranular	Plagioclase 35 Orthopyroxene(?) 1 Total 3)	Plagioclase 30 Clinopyroxene 15 Glass 10 Ore 6 Orthopyroxene(?) 3 Quartz 3 100	Chlorite 1 Chlorophaeite Smectite(?)	Plagioclase 34 Orthopyroxene(?) 1 Total	Plagioclase 30 Clinopyroxene 15 Glass 10 Ore 6 Orthopyroxene(?) 2 Quartz 2 100	Chlorite Chlorite Analcite(?) Leucoxene Sericite(?) Smectite(?) Kaolinite	Opa(?), glass Opa(?) Glass Ore Plagioclase (Smectic) Plagioclase	8 3 2 2 <1 <1 <1	Massive flow from east side of Chilaqua Bay, north side of island. Plagioclase is uniformly glomeroporphyric with itself and rare, totally altered opa(?), includes matrix phases and totally altered glass, and is lamellarized and sericitized; matrix plagioclase is also altered similarly; ore is skeletal to dendritic in aspect and is highly altered; glass is totally altered.
28. 770-11-4B Basalt [7]	Intersertal, subtrachytic	Clinopyroxene 6 Ore 5 Plagioclase 1 Total 3)	Plagioclase 43 Glass 17 Clinopyroxene 11 Quartz 10 Orthopyroxene(?) 6 Ore <1 Apatite <1 99+	None			Chlorophaeite Kaolinite Quartz Leucoxene Prehnite(?) Sericite(?) Hematite	Glass,opa(?),duster. (Smectic) (Smectic) Ore Plagioclase,duster. Plagioclase Ore	37 10 8 2 1 <1 <1	Data, same locality as 11-4A. Plagioclase is usually unit phyric, infrequently glomeroporphyric with cpx and ore, and is highly altered; cpx varies in color from pale smoky yellow to purplish-neutral, partially ophitic matrix plagioclase, in both microphyric and glomeroporphyric, and is partly resorbed; ore is hypidiomorphic and glomeroporphyric, and as a matrix phase, is highly altered to leucoxene and hematite; glass is totally altered; cpx includes microlithic apatite.
27. 770-11-4B Basalt	Intersertal	Clinopyroxene 7 Ore 5 Plagioclase 2 Total 3)	Plagioclase 33 Clinopyroxene 27 Glass 10 Quartz 5 Orthopyroxene 1 Ore 1 100	Quartz 1	Clinopyroxene 7 Ore 5 Plagioclase 2 Total	Plagioclase 34 Clinopyroxene 27 Glass 10 Quartz 5 Orthopyroxene 1 Ore 1 100	Chlorophaeite/Smectite Quartz Sericite(?) Hematite	Glass (Smectic) Plagioclase Ore	10 1 <1 <1	Clast from volcanic sandstone, same locality as 11-4B. Plagioclase is unit phyric, infrequently glomeroporphyric with cpx and ore; cpx is usually microphyric, neutral in color, and often subophitically encloses plagioclase laths; ore is microphyric and microglomeroporphyric, and is partly altered to hematite; matrix cpx is remarkably fresh and faintly pleochroic from pinkish to greenish; quartz occurs as blob-like bodies in totally altered glass.
28. 770-11-5A Hyalite[7]	Hyalopilitic	Plagioclase 3 Clinopyroxene <1 Ore <1 Orthopyroxene(?) <1 Total 3)	Plagioclase 34 Glass 36 Quartz 14 Clinopyroxene 11 Ore 2 Orthopyroxene(?) 1 99+	None			Smectite Chlorophaeite Hematite Quartz Kaolinite Sericite(?) Pumpellyite(?) Epidote	Glass Glass Glass,ore,sulfide (Smectic) Plagioclase Plagioclase Plag., (Smectic) (Smectic)	55 15 5 5 4 2 1 <1	Pillow lava interior, east of Cape Idaloq, north side of island. Plagioclase is glomeroporphyric with cpx, opa(?), and ore, and is lamellarized and sericitized; cpx is neutral in color and quite fresh; opaque totally altered; ore is glomeroporphyric with pyroxenes only, displays evidence of resorption and alteration to hematite; matrix plagioclase is microlithic and is felted intergrowth with highly altered cpx; matrix ore is highly altered, matrix opa(?) is totally altered; glass is totally altered.

Table 4,cont.

29. 770-11-6A Hyalite[7]	Hyalopilitic	Plagioclase	10	Plagioclase	39	Chlorophaeite	<1				Chlorophaeite	Glass,pyroxene	17	Massive flow with columnar jointing, from semicircular bay four miles east of Cape Idaluq. Plagioclase is glomerophyric with cpx, opx(?), and ore, is altered internally, and displays evidence of resorption; cpx is neutral in color and includes glass and microlitic apatite; opx(?) is totally altered and is occasionally unit phyric as well as glomerophyric; ore is occasionally unit phyric as well as glomerophyric; both phyric and matrix ores are are highly altered; glass is totally altered; quartz is abundant as minute blebs in the glass.
		Orthopyroxene(?)	1	Glass	27						Zeolites	Glass,plag.	10	
		Ore	<1	Quartz	14						Kaolinite	Plagioclase	4	
		Clinopyroxene	<1	Clinopyroxene	7						Hematite	Glass,ore,pyrox.	4	
				Ore	2						Pumpellyite(?)	Glass, Plag.	2	
		Total 2)		Apatite	<1						Sericite(?)	Plagioclase	<1	
				100+										
30. 770-11-6B Andesite	Hyalopilitic	Plagioclase	12	Glass	58	Quartz	2	Plagioclase	12	Glass	59	Smectite	Glass	1	Glassy flow margin of 11-6A, same locality. Plagioclase is unit phyric and also glomerophyric with cpx, opx, and ore; cpx is neutral in color and often ophitically enclose microphyric ore; opx is remarkably fresh and faintly pleochroic from pinkish to greenish; ore is both unit phyric and glomerophyric; matrix phases are microlitic and generally acicular in form; glass seems quite fresh except for dissolved hematite dust. Large apatite needles occur as inclusions in plagioclase and pyroxene.
		Orthopyroxene	2	Plagioclase	10	Smectite		Orthopyroxene	2	Plagioclase	10	Zeolites	Glass	1	
		Ore	2	Clinopyroxene	7	Zeolites		Ore	2	Clinopyroxene	7	Hematite	Glass	1	
		Clinopyroxene	2	Ore	3			Clinopyroxene	2	Ore	3	Quartz	(Deuteric)	<1	
				Orthopyroxene	2					Orthopyroxene	2				
		Total 2)		Apatite	<1					Apatite	<1				
				100+				Total		99+					
31. 770-11-6C Hyalite	Hyalopilitic to holohyaline	Plagioclase	~5	Glass	75-70	Quartz	1-75					Quartz	(Deuteric)	50-75	Green altered Hyalite, same locality as 11-6A. Composite sample with three distinct lithologies: a)original rock ?)-glass charged with plagioclase and orthoclase(?) glomerophyric with greenish-neutral, sparry cpx, totally altered opx, and ore. b) glass, darker in color and more opaque than (a), probably representing an inclusion of older, more altered material with similar texture and phases. (c) glass, totally altered and cellular, perhaps originally a froth with gas cavities now filled with quartz.
		Orthoclase(?)	~3	Plagioclase	7-10	Smectite	(Varies					Chalcedonite	Glass	5-50	
		Clinopyroxene	1	Clinopyroxene	<1-5	Zeolites	greatly					Smectite	Glass, mafics	25	
		Ore	1	Orthopyroxene	~2		within the					Goethite(?)	Glass	5	
		Orthopyroxene	1	Ore	<1-1		section)					Kaolinite	Plagioclase	1	
				Apatite	<1							Hematite	(Deuteric)	1	
		Total 2)		100								Manganic oxide(?	Deuteric)	1	
												Sericite(?)	Plagioclase	<1	
32. 770-11-6D Hyalite[7]	Hyalopilitic	Plagioclase	1	Glass	32	Quartz	5	Plagioclase	1	Glass	33	Zeolites	(Deuteric)	15	Massive columnar Hyalite, same locality as 11-6A. Plagioclase is highly altered as glomerophyric with neutral -colored cpx, hypidiomorphic ore, and rare, totally altered opx(?); matrix Plagioclase and cpx are microlitic and highly altered; matrix ore displays two distinct grain sizes; glass is totally altered; quartz is abundant as minute blebs in the glass; microlitic apatite observed as inclusions in cpx.
		Clinopyroxene	1	Quartz	24	Zeolites		Clinopyroxene	1	Quartz	25	Smectite	Glass	9	
		Orthoclase(?)	1	Plagioclase	21			Orthoclase(?)	1	Plagioclase	22	Hematite	Glass	7	
		Ore	<1	Clinopyroxene	9			Ore	<1	Clinopyroxene	9	Quartz	(Deuteric)	5	
				Ore	4					Ore	4	Pumpellyite(?)	Feld.,px.,	4	
		Total 2)		Orthoclase(?)	3					Orthoclase(?)	3		?Deuter.)		
				101+				Total		99+		Kaolinite	Plagioclase	4	
												Leucoxene	Ore	1	
												Chlorophaeite	Cpx(?)	<1	

Table 5,cont.

33. 779-13-1B(1)	Basalt	Intergranular to intersertal	Plagioclase	28	Plagioclase	18	Smectite	20	Plagioclase	25	Plagioclase	22	Smectite	Glass, cpx(?)	10	Clast in volcanic breccia, small bay about 10 miles east of Cape Idaluq, north of side of island. Plagioclase is sometimes unit phyric, more often glomerophyric, with totally altered cpx(?) and fresh, neutral-colored cpx, which are both unit phyric and glomerophyric also; both matrix and phyric plagioclase display minor deuteritization, zeolitization, sericitization, and kaolinitization; matrix cpx is granular in habit and quite fresh; glass is totally altered.
			Orthopyroxene(?)	2	Clinopyroxene	18	Zeolites		Orthopyroxene(?)	3	Clinopyroxene	22	Kaolinite	Plagioclase	2	
			Clinopyroxene	2	Ore	10			Clinopyroxene	3	Ore	12	Calcite	Cpx(?)	2	
					Glass	10					Glass	12	Zeolites	(Deuteric)	<1	
			Total 2)		100				Total		99+		Sericite(?)	Plagioclase	<1	
													Epidote	Plagioclase	<1	
34. 779-13-1B(2)	Basalt	Microlitic intergranular	Plagioclase	25	Clinopyroxene	24	Chlorophaeite	15	Plagioclase	29	Clinopyroxene	28	Chlorophaeite	Cpx(?),deuteric	26	Clast from same volcanic breccia as 13-1B(1). Plagioclase is unit phyric and also glomerophyric, frequently with itself and cpx(?), rarely with cpx, which is usually unit phyric, sometimes glomerophyric with plagioclase (often poikilitically enclosed by it), and is neutral in color; cpx(?) is totally altered and usually unit phyric, but is also glomerophyric, displaying embayed, resorbed crystals; matrix plagioclase and cpx display two distinct grain sizes; matrix cpx(?) is totally altered and displays a distinctly coarser grain size than the other matrix phases; matrix ore is microlitic with a dendritic aspect.
			Orthopyroxene(?)	5	Plagioclase	20	Calcite		Orthopyroxene(?)	6	Pigioclase	24				
			Clinopyroxene	5	Ore	5	Zeolites		Clinopyroxene	6	Ore	6	Calcite	Cpx(?),deuteric	5	
					Orthopyroxene(?)	1					Orthopyroxene(?)	1	Kaolinite	Plagioclase	2	
			Total 2)		100				Total		100		Zeolites	(Deuteric)	<1	
35. 779-13-2A	Basalt 4)	Intergranular to intersertal	Plagioclase	34	Plagioclase	31	None									Massive columnar flow, west side of major bay east of "360" Cove. Plagioclase is glomerophyric mainly with itself, rarely with cpx(?), includes totally altered glass, and is highly kaolinitized, deuteritized, and sericitized(?); cpx(?) is totally altered and usually unit phyric, rarely glomerophyric; matrix plagioclase displays two distinct grain sizes; matrix cpx(?) is totally altered, matrix cpx is neutral in color and granular in habit; matrix ore displays three distinct grain sizes; glass is totally altered.
			Orthopyroxene(?)	2	Clinopyroxene	7							Chlorite	Glass, cpx(?)	14	
			Clinopyroxene	1	Glass	7							Epidote	Plag., glass	14	
					Ore	5							Kaolinite	Plagioclase	4	
					Orthopyroxene(?)	2							Magnetite(?)	Glass	1	
			Total 3)		100								Sericite(?)	Plagioclase	<1	
													Leucoxene	Ore	<1	
36. 779-13-2B	Hyalite 5)	Spherulitic	Plagioclase	2	Glass	45	Zeolites	1	Plagioclase	2	Glass	48	Quartz	(Deuteric)	6	Pillow lava interior, same locality as 13-2A. Plagioclase is usually glomerophyric with cpx and ore, rarely unit phyric; orthoclase(?) is glomerophyric and, with plagioclase, is kaolinitized and deuteritized; cpx is glomerophyric and neutral in color; ore tends to be microphyric and included in large cpx crystals, or as unit crystals on matrix; groundmass is composed of microlites suspended in highly altered glass charged with hematite dust; quartz is abundant as blebs and veinlets.
			Orthoclase(?)	2	Quartz	22	Chlorophaeite		Orthoclase(?)	2	Quartz	23	Pumpellyite(?)	Plag.,glass,cpx	4	
			Clinopyroxene	1	Plagioclase	10			Clinopyroxene	1	Plagioclase	11	Hematite	Glass, cpx	3	
			Ore	<1	Clinopyroxene	6	Quartz	6	Ore	<1	Clinopyroxene	9	Smectite	Glass, cpx	2	
					Ore	4	(Veinlets)				Ore	4	Kaolinite	Plagioclase	1	
			Total 3)		Orthoclase(?)	3			Total		Orthoclase(?)	2	Zeolites	(Deuteric)	1	
					101+						99+		Epidote	Feldspars	<1	

Table 5, cont.

37. 779-13-4	Basalt	Hyalopilitic to microlitic intergranular	Plagioclase Clinopyroxene Orthopyroxene(?)	1 1 <1	Glass Plagioclase Clinopyroxene Ore Orthopyroxene(?) 100+	35 11 14 10 2	Smectite Zeolites	28	Plagioclase Clinopyroxene Orthopyroxene(?) Total	1 1 <1	Glass Plagioclase Clinopyroxene Ore Orthopyroxene(?) 99+	50 34 14 14 3	Zeolites Smectite Quartz Calcite Chlorophaeite	(Deuteric), feldspar Glass (Deuteric) Cpx(?) Cpx(?)	42 20 5 2 1	Massive flow along north side of Hungry Bay. Plagioclase is highly zeolitized and is glomerophyric with fresh, neutral-colored cpx; cpx(?) is unit phyric and totally altered; matrix phases are microlitic except for cpx(?) which is larger than the others; glass is totally altered.
38. 779-13-14B	Basalt [7]	Intergranular	Plagioclase Clinopyroxene Orthopyroxene(?) Total [3]	31 8 <1	Clinopyroxene Plagioclase Glass Ore 100	34 14 14 7	Chlorite	10	Plagioclase Clinopyroxene Orthopyroxene(?) Total	34 9 <1	Clinopyroxene Plagioclase Glass Ore 99+	38 15 15 8	Zeolites Analcite(?) Smectite Kaolinite Chlorite Pumpellyite(?) Sericite(?)	Plagioclase Glass, plag. Clinopyroxene Plagioclase Glass, opx(?) Plagioclase Plagioclase	20 11 8 7 7 <1 <1	Massive flow from north side of Hill "1732", south of Hungry Bay, el. 1050 ft. Plagioclase is unit phyric and also glomerophyric with neutral-colored cpx and, rarely, totally altered opx(?), includes much totally altered glass, and displays incipient to intense zeolitization, kaolinitization, and sericitization(?); opx(?) is usually unit microphyric; matrix phases are generally microlitic; glass is totally altered.
39. 779-13-14D	Andesite	Hyalopilitic	Plagioclase Clinopyroxene Orthopyroxene Ore Total [3]	12 5 1 <1	Glass Plagioclase Clinopyroxene Quartz Ore Orthopyroxene(?) 100+	30 15 15 10 7 5	Empty	10	Plagioclase Clinopyroxene Orthopyroxene Ore Total	13 6 1 <1	Glass Plagioclase Clinopyroxene Quartz Ore Orthopyroxene(?) 100+	33 11 11 11 8 6	Smectite Zeolites Chlorophaeite Hematite Kaolinite Amphibole(?) Sericite(?)	Glass, opx Glass Glass, opx Glass, opx Plagioclase Glass, opx Plagioclase	25 5 5 3 2 1 1	Massive flow from Hill "1732", sampled at el. 1120 ft. ft. Plagioclase is glomerophyric with idiolf. neutral-to-greenish-colored cpx, microphyric ore, and remarkably fresh opx; includes totally altered glass, and displays kaolinitization and sericitization(?); matrix phases are generally microlitic and set in totally altered glass.
40. 779-14-1A	Basalt	Microlitic intergranular	Plagioclase Clinopyroxene Orthopyroxene Total [3]	29 4 2	Plagioclase Clinopyroxene Ore Orthopyroxene(?) 100	28 28 10 1	Chlorophaeite Quartz Calcite Zeolites	7	Plagioclase Clinopyroxene Orthopyroxene Total	22 4 3	Plagioclase Clinopyroxene Ore Orthopyroxene(?) 100	30 30 11 1	Chlorophaeite Smectite Zeolites Calcite Analcite Quartz	Orthopyroxene(?) Orthopyroxene(?) Plagioclase, (Deuteric) Orthopyroxene(?) (Deuteric) (Deuteric)	5 5 5 2 3 1	Clast in coarse volcanic breccia from major point just south of Amlia Pass. Plagioclase is generally glomerophyric with idiolf. cpx, and opx, displays incipient kaolinitization and sericitization, and includes much altered glass; cpx displays a pale greenish color and is usually unit phyric, rarely glomerophyric; opx is remarkably fresh and faintly pleochroic in greenish and pinkish tints, and is usually unit phyric, rarely glomerophyric; matrix phases generally display several distinct grain sizes each.

Table 5.-cont.

41. 779-14-19	Basalt	Microlitic (aphanitic to intergranular	Plagioclase	25	Plagioclase	25	Chlorophaeite	2	Plagioclase	35	Plagioclase	34	Chlorophaeite	Glass,opa(?), olivine(?)	7	Glass is colorless brownish, some locations as 14-18. Plagioclase is unit phyric, strongly zoned, rimmed with fresh, cored with kaolinitized and serecitized(?) feldspar, and includes dark altered glass; cpx is neutral in color, is usually unit phyric, and often includes matrix phases; ore is microphyric and included, or is included by cpx crystals; opa(?) and olivine(?) are totally altered, usually unit phyric, rarely glomerophyric; matrix phases display several distinct grain sizes each and are set in rather fresh, brownish glass.
			Clinopyroxene	9	Clinopyroxene	25			Clinopyroxene	9	Clinopyroxene	26				
			Orthopyroxene(?)	2	Glass	5			Orthopyroxene(?)	2	Glass	4	Kaolinite	Plagioclase	5	
			Olivine(?)	1	Ore	4			Olivine(?)	1	Ore	6	Calcite	Opa(?),ol(?)	<1	
			Ore	<1	Orthopyroxene(?)	1			Ore	<1	Orthopyroxene(?)	1	Sericite(?)	Plagioclase	<1	
			Total 3)		Olivine(?)	1			Total		Olivine(?)	1				
					100+						100+					
42. 779-14-24	Basalt	" Intersertal	Plagioclase	30	Glass	21	Chlorite	14	Plagioclase	34	Glass	34	Chlorophaeite	Glass, (Devitrite)	21	Dike near Eddy Point, north side of island. Plagioclase is usually glomerophyric with itself, less often with cpx, is generally rimmed with fresher feldspar, includes much totally altered glass, and displays intense kaolinization and serecitization; cpx is neutral in color and macrophyric, the crystals often poikilitically enclosed in larger plagioclases; grain sizes and textures display extreme variation within the section; glass is totally altered.
			Clinopyroxene	5	Plagioclase	18	Zeolites		Clinopyroxene	6	Plagioclase	31				
					Clinopyroxene	18					Clinopyroxene	12	Kaolinite	Plagioclase	19	
					Ore	3					Ore	3	Chlorite	(Devitrite)	6	
			Total 3)		101				Total		100		Zeolites	(Devitrite)	2	
													Sericite(?)	Plagioclase	<1	
43. 779-14-48	Basalt	" Intersertal	Plagioclase	23	Glass	31	Empty	2	Plagioclase	34	Glass	32	Chlorophaeite	Glass, opa(?), olivine	17	Massive flow base along west side of first major bay west of Hungry Bay. Plagioclase is generally glomerophyric with itself and cpx,and is strongly zoned and altered; cpx is neutral in color and is sometimes poikilitically enclosed by plagioclase; opa(?) and olivine(?) are totally altered and more frequently glomerophyric with themselves only than with other phyric phases; matrix phases are microlitic to very granular in form; glass is totally altered.
			Clinopyroxene	3	Clinopyroxene	19			Clinopyroxene	3	Clinopyroxene	20				
			Orthopyroxene(?)	1	Plagioclase	15			Orthopyroxene(?)	1	Plagioclase	15	Pumpellyite(?)	Glass,plag.	15	
			Olivine(?)	<1	Ore	5			Olivine(?)	<1	Ore	5	Kaolinite	Plag., glass	8	
			Total 3)		99+				Total		100+		Calcite	Opa(?), ol(?)	1	
													Kaolinite	Plagioclase	<1	
44. 779-14-50	Basalt	" Spilolitic	Plagioclase	45	Glass	38	Rarely lined with quartz, smectite	2	Plagioclase	44	Glass	38	Smectite	Glass	38	Flow interior, some locations as 14-18. Plagioclase is glomerophyric with itself, cpx,and ore, or is rarely unit phyric, and includes much glass; cpx is neutral in color and glomerophyric with other phyric phases except opa(?); ore is microphyric, is often included in pyroxenes, and displays a characteristic chemical aspect; matrix phases generally display several distinct grain sizes each; glass is totally altered; quartz occurs as blob-like bodies in the glass.
			Clinopyroxene	12	Plagioclase	6			Clinopyroxene	12	Plagioclase	6				
			Ore	2	Quartz	4			Ore	2	Quartz	4				
			Orthopyroxene(?)	<1	Ore	3			Orthopyroxene(?)	<1	Ore	2				
			Total 2)		Clinopyroxene	1			Total		Clinopyroxene	1				
					100+						99+					

Table 1, cont.

65. 770-14-4C	Hawaii	"	Intersertal	Plagioclase	35	Glass	34	Chlorophaeite	4	Plagioclase	37	Glass	25	Smectite	Glass	21	Flow interior, same location as 14-4A. Plagioclase is usually glomerophyric with itself, infrequently with cpx, and is also unit phyric; cpx is neutral in color and usually glomerophyric with cpx(?), which is both glomerophyric and unit phyric, and is totally altered; matrix phases generally display two distinct grain sizes each; cpx frequently includes microlites of plagioclase and ore; glass is totally altered.
				Clinopyroxene	6	Plagioclase	16	Smectite		Clinopyroxene	6	Plagioclase	17	Chlorite	Glass	3	
				Orthopyroxene(?)	1	Clinopyroxene	7			Orthopyroxene(?)	1	Clinopyroxene	7	Zeolites	Glass	1	
						Quartz	5					Quartz	5				
				Total 2)		Ore	4			Total		Ore	4				
						100						100					
66. 770-14-4D	Hawaii	"	Spilosphitic	Plagioclase	47	Glass	21	None									Top of flow, same locality as 14-4A. Plagioclase is both unit phyric and glomerophyric with cpx and ore, and is much kaolinitized internally; cpx is neutral in color, granulated internally, and glomerophyric with other phyric phases; ore is glomerophyric with other phyric phases and is decidedly skeletal; matrix phases are quite granular in habit, with cpx subophitically enclosing other phases; matrix ore is quite skeletal in aspect; glass is totally altered.
				Clinopyroxene	11	Quartz	12							Smectite	Glass, (Devitric)	19	
				Ore	3	Plagioclase	4							Zeolites	Glass	2	
						Clinopyroxene	1							Zeolite	Plagioclase	<1	
				Total 2)		Ore	1							Amphibole(?)	Glass	<1	
						100											
67. 770-14-25A	Oahu	"	Porphyritic granular	Plagioclase	6	Plagioclase	65	None									Hypabyssal pluton, north side of Hungry Bay. Plagioclase is glomerophyric with neutral-colored cpx, includes altered glass, and is itself highly altered; cpx poikilitically encloses matrix phases; ore is glomerophyric with other phyric phases and is quite skeletal in aspect; opx(?) is totally altered and is glomerophyric with all other phyric phases except plagioclase; matrix phases differ but little from the phyric phases except by size; glass is totally altered.
				Clinopyroxene	3	Clinopyroxene	14							Chlorite	Opx(?), cpx	9	
				Orthopyroxene(?)	1	Glass	10							Amphibole	Clinopyroxene	1	
				Ore	<1	Ore	1							Zeolites	Glass	1	
						Orthopyroxene(?)	1							Hematite	Ore	<1	
				Total 2)		100								Smectite	Opx(?), glass	<1	
														Herzenite(?)	Plagioclase	<1	
														Leucoxene	Ore	<1	
68. 770-14-25B	Oahu	"	Porphyritic granular	Plagioclase	30	Plagioclase	39	None									Hypabyssal pluton, north side of Hungry Bay. Plagioclase is usually unit phyric, rarely glomerophyric with cpx, includes altered glass, is strongly zoned, and displays evidence of resorption; cpx is neutral in color, often unit phyric or glomerophyric with opx(?) only, and often ophitically encloses the opx(?) and also plagioclase; opx(?) is totally altered and is both unit phyric and glomerophyric; matrix phases reflect the phyric phases on a smaller scale; microlitic apatite, quartz, and biotite(?) occur in pools of totally altered glass.
				Clinopyroxene	7	Glass	19							Smectite	Glass, opx(?), plagioclase	20	
				Orthopyroxene(?)	5	Clinopyroxene	9										
						Orthopyroxene(?)	7							Pumpellyite(?)	Plag., glass	3	
						Ore	3							Herzenite(?)	Plagioclase	<1	
						Apatite	1										
				Total 2)		Biotite(?)	<1										
						100+											

Table 1, cont.

68.770-16-W	Basalt	Incremental	Plagioclase	35	Glass	20	Calcite	1	Plagioclase	35	Glass	20	Hematite	Glass, opal(?)	20	Remove flow rock, north side of Humpy Bay. Plagioclase is usually euhedral, is strongly zoned, and displays considerable evidence of resorption. Cpx is neutral in color, microphenocrystic with itself or with ore, sporadically surrounds matrix plagioclase, and displays strong sector-zoning. Ore is phenocrystic and highly euhedral in aspect; matrix plagioclase displays a wide range of grain sizes; matrix cpx and ore are like those phyric counterparts in aspect; opal(?) and glass are totally altered.
			Clinopyroxene	32	Quartz	11	Hematite		Clinopyroxene	32	Quartz	11	Limonite	Ore	<1		
			Ore	4	Plagioclase	6			Ore	4	Plagioclase	6	Chlorite	Opal(?),Phenocrysts			
					Ore	1					Ore	1					
			Total	72	Orthopyroxene(?) Xtls	<1			Total		Orthopyroxene(?) Xtls	<1					

Table 6. Representative microprobe analyses of plagioclase, Amlia Island volcanic rocks. David Clague and Walter Friesen, Analysts.

	779-14-25A (Gabbro)				779-7-6B (Basalt)			
	1	2	3	4	PC1	PC2	PC3	PC4
SiO_2	46.88	45.95	47.98	48.29	48.33	47.84	46.75	50.83
Al_2O_3	33.52	33.90	32.61	32.34	32.62	33.07	34.33	31.10
FeO_T	0.66	0.66	0.82	0.79	0.93	0.91	0.88	0.95
CaO	18.10	18.63	16.60	17.25	16.20	16.58	16.77	14.65
Na_2O	1.32	1.01	1.84	1.87	2.11	2.11	2.07	3.22
K_2O	0.03	0.04	0.06	0.05	0.08	0.07	0.06	0.11
Total	100.51	100.19	99.91	100.59	100.26	100.58	100.86	100.86
Atomic proportions, O = 8								
Si	2.152	2.120	2.207	2.211	2.215	2.190	2.138	2.306
Al	1.814	1.844	1.768	1.745	1.762	1.784	1.851	1.663
Fe^{+2}	0.025	0.026	0.032	0.030	0.036	0.035	0.034	0.036
Ca	0.890	0.921	0.818	0.846	0.796	0.813	0.822	0.712
Na	0.117	0.091	0.164	0.166	0.187	0.187	0.183	0.283
K	0.002	0.002	0.003	0.003	0.005	0.004	0.003	0.006
Or, mol%	0.2	0.2	0.3	0.3	0.5	0.4	0.3	0.6
Ab, mol%	11.6	9.0	16.7	16.4	18.9	18.6	18.2	28.3
An, mol%	88.2	90.8	83.0	83.3	80.6	81.0	81.5	71.1

Table 6. (Continued)

	779-11-4A (Basalt)		779-15-1C (Basalt)			779-11-2 (Basalt)		
	1	2	PC1	PC2	PC3	PC1	PC2	PC3
SiO_2	48.81	48.43	49.69	54.26	49.79	45.22	50.18	52.76
Al_2O_3	32.39	32.40	32.11	28.87	31.66	35.44	32.10	29.91
FeO_T	0.65	0.63	0.92	0.69	0.92	0.75	0.94	0.86
CaO	17.47	17.05	14.86	11.28	14.57	17.88	14.51	13.29
Na_2O	1.69	1.83	3.01	4.99	2.87	1.23	3.05	3.93
K_2O	0.06	0.06	0.08	0.12	0.06	0.03	0.10	0.14
Total	101.07	100.40	100.67	100.21	99.87	100.55	100.88	100.89
Atomic proportions, 0 = 8								
Si	2.221	2.217	2.261	2.451	2.279	2.078	2.275	2.381
Al	1.737	1.748	1.722	1.537	1.708	1.920	1.715	1.591
Fe^{+2}	0.025	0.024	0.035	0.026	0.035	0.029	0.036	0.032
Ca	0.851	0.836	0.725	0.546	0.715	0.880	0.705	0.642
Na	0.149	0.162	0.266	0.437	0.255	0.110	0.268	0.344
K	0.003	0.004	0.004	0.007	0.004	0.002	0.006	0.008
Or, mol%	0.3	0.4	0.4	0.7	0.4	0.2	0.6	0.8
Ab, mol%	14.9	16.2	26.7	44.1	26.2	11.1	27.4	34.6
An, mol%	84.8	83.4	72.9	55.2	73.4	88.7	72.0	64.6

Table 6. (Continued)

	779-9-1B (Bas. Andesite)		779-14-4B (Bas. Andesite)			
	PC1	PC2	PC1	PC2	PC3	PC4
SiO_2	50.83	54.23	50.49	46.89	50.23	50.74
Al_2O_3	31.10	28.48	29.28	32.59	30.45	29.54
FeO_T	0.95	0.84	1.04	0.86	1.16	1.05
CaO	14.65	10.98	13.73	17.62	14.25	13.42
Na_2O	3.22	5.14	3.63	1.47	3.22	3.73
K_2O	0.11	0.12	0.13	0.05	0.11	0.14
Total	100.86	99.79	98.30	99.48	99.42	98.62
Atomic proportions, 0 = 8						
Si	2.306	2.461	2.349	2.175	2.313	2.351
Al	1.663	1.523	1.606	1.782	1.653	1.614
Fe^{+2}	0.036	0.032	0.040	0.033	0.045	0.040
Ca	0.712	0.534	0.685	0.876	0.703	0.665
Na	0.283	0.452	0.328	0.132	0.288	0.335
K	0.006	0.007	0.008	0.003	0.006	0.008
Or, mol%	0.6	0.7	0.8	0.3	0.6	0.8
Ab, mol%	28.3	45.5	32.1	13.1	28.9	33.2
An, mol%	71.1	53.8	67.1	86.6	70.5	66.0

Table 6. (Continued).

	779-8-1B (Andesite)				779-9-3B (Rhyolite)	
	PC1	PC2	PC3	PC4	PC1	PC2
SiO_2	54.98	55.61	54.55	55.21	56.54	56.17
Al_2O_3	28.28	27.64	28.74	28.09	27.41	27.40
FeO_T	0.63	0.62	0.63	0.60	0.63	0.58
CaO	11.76	10.61	10.80	10.45	8.89	9.57
Na_2O	4.75	5.22	5.21	5.17	6.11	5.74
K_2O	0.20	0.32	0.25	0.57	0.13	0.13
Total	100.60	100.02	100.18	100.09	99.71	99.59
Atomic proportions, 0 = 8						
Si	2.474	2.510	2.463	2.493	2.547	2.536
Al	1.500	1.470	1.529	1.495	1.455	1.458
Fe^{+2}	0.024	0.023	0.024	0.023	0.024	0.022
Ca	0.567	0.513	0.522	0.506	0.429	0.463
Na	0.414	0.457	0.456	0.453	0.534	0.502
K	0.024	0.018	0.014	0.033	0.008	0.022
Or, mol%	2.4	1.8	1.4	3.3	0.8	2.2
Ab, mol%	41.2	46.3	46.0	45.7	55.0	50.9
An, mol%	56.4	51.9	52.6	51.0	44.2	46.9

rich sanidine in composition. They are, in general, rarely phanerocrystalline and are, when phaneritic, mostly very highly altered. The clinopyroxene is generally augite, often displaying a black or greenish-black color in hand specimen and, usually, a neutral color in thin section. Optically, they yield inclined extinctions to about 45°, with an axial angle (2E) of about 60°. They often include acicular microlites of apatite, characteristic of tholeiitic differentiation. Orthopyroxene (rarely unaltered) is, in general, iron-poor hypersthene. It is faintly pleochroic from pale pink to pale green and generally yields an axial angle (2E) of about 65°, indicating the presence of about 30 percent ferrosilite end-member. No fresh olivine was observed in any of the Amlia samples, but some of the basalts have calcite pseudomorphs bearing the rhombic aspect of olivine crystals. Ore phases occur as phenocrysts in nearly all the Amlia igneous rocks. Phenocrysts of elongate orthogonal and large hexagonal aspect often display gray reflectance with a violet tint, and are often altered peripherally and internally to leucoxene. Cubic and rhombic ore phases generally display gray reflectance with a bluish tint. Some of these phases have altered superficially to leucoxene and hematite. More have altered to hematite alone. Some are so completely altered to hematite that they are uniformly translucent in blood-red hues. The primary mineral phases present in the ores are probably magnetite, titanomagnetite, and ilmenite. Quartz does not occur as phenocrysts in the rocks of Amlia Island, yet it is a constituent in many samples where it often appears as an anhedral groundmass phase. More frequently, quartz appears as microscopic to submicroscopic rounded blebs that apparently crystallized from glass. Primary biotite(?) was observed only in a gabbro sample from a small hypabyssal intrusion exposed on the north side of Hungry Bay. All other biotite(?) observed appears to be secondary. Primary amphibole was noted only in a tonalite sample from a sill exposed at the first bay east of Sharp Point.

It appears from the mineralogy observed in thin section, hand specimen, and in the field that the igneous rocks of Amlia Island were derived from magmas of calc-alkaline and tholeiitic character. They are not characteristic of olivine-rich mid-ocean ridge petrogenesis nor of the silica-poor, alkali-olivine basalts associated with Hawaiian-type island chains. The simple and rather continuous primary mineralogy of calcic plagioclase, augite, and hypersthene, iron-titanium oxide ore phases, apatite, and rather rare quartz suggests island arc or continental margin-type volcanism.

There is considerable evidence in thin section indicating that crystallization occurred close to the liquidus and that some wallrock or earlier crystallizing phases were incorporated in the magmas that formed the Amlia rocks. Most of the rocks, even the intrusive ones, are glomerophyric, and usually bear numerous isolated phenocrysts as well. Orthopyroxene is least commonly glomerophyric and occurs as small euhedra. Perhaps this indicates initial slow cooling and stable conditions as crystallization began in the magma chamber or chambers, allowing the uninhibited crystallization of the orthopyroxene in a rather viscous melt. Plagioclase, too, is frequently an isolated phenocryst, as are clinopyroxene and the ore phases. Rarely, however, are any of the last three phases euhedral, and they often show evidence of resorption. Plagioclase and clinopyroxene frequently display strong zonation, indicating later changes in magmatic composition. Often, all four major phenocryst phases are found grown together in small clusters of half-a-dozen to a dozen crystals. In sample 8-1B, a few gabbroic xenolith-like clusters were observed suspended in a much finer-grained groundmass.

These observations suggest much crystal settling with subsequent disturbance and mobilization of crystals in the magma, accompanied by influxes of material (perhaps by stoping of wall rock) of different composition. Plagioclase and clinopyroxene often include numerous blebs of glass, indicating rapid crystal growth and resorption. Groundmass phases are often included in feldspar and clinopyroxene phenocrysts, indicating late, rapid, phenocryst growth.

Ongoing magmatic activity was likely responsible for the low-grade metamorphism of the Amlia rocks. The rocks have been hydrothermally altered, beginning with ubiquitous smectitization and proceeding through the rarer and more isolated saussuritization. The exposed stratigraphic sequence on Amlia is cut by numerous dikes, sills, and small, stock-like hypabyssal intrusions composed of rocks similar in composition to their hosts. Since different types of alteration such as smectitization, sericitization, kaolinitization, zeolitization, and calcitization are virtually ubiquitous throughout the island, and rather uniform in their effect, it may be suggested that several types of metasomatic activity probably were at work through space and time and were rather regional in scope. McLean and others (1981) proposed batholithic-scale intrusion in the region of nearby Atka Island as the source for the generalized heating, deformation, and exhalative activities responsible for the alteration of the Amlia rocks, and localized intrusion by feeders to supply the higher temperatures and fluids necessary for saussuritization and intense zeolitization. Some of these same, or at least similar, plutons may extend beneath the outcrops on Amlia Island.

Apparently, the first phases to be altered in the rocks were olivine and orthopyroxene. They are typically altered to calcite or calcite and smectites. The alteration, sometimes only patchy, is least severe in rocks from the southeast end of the island. This is typically where the youngest rocks are exposed. Perhaps the earliest fluids migrating through the rocks were rich in CO_2, H_2O, silicon, calcium, sodium, and aluminum. In several rocks from western Amlia, calcite replacement of orthopyroxene was succeeded by alkali-rich smectite and then by alkali-iron smectite (chlorophaeite) in successive rims.

Ore phases display minor to total alteration throughout the exposed volcanic pile. The principal alteration products are hematite and leucoxene. Heating, and changes in water vapor pressure due to magma chamber breaching, together with freely-migrating oxygen in hydrothermal fluids, could account for the partial-to-total oxidation of the ore phases to hematite and anatase(?) (leucoxene) that is frequently seen in the Amlia rocks. Alteration of the ores to hematite is seen in all Amlia rocks, but is most intense and complete in samples from the north central coast. Leucoxene alteration is apparent only in the eastern three-quarters of the island, with the greatest intensity observed in rocks from the north central coast.

Clinopyroxene and its included apatite are the least altered of all the phases encountered in the Amlia rocks. Although frequently rather deformed, sector-zoned, resorbed, and internally granulated, clinopyroxene generally stands out fresh amid its more altered neighbors. Although alteration of clinopyroxene is infrequent, the usual products are smectite, pumpellyite, or amphibole. The amphibolization may represent deuteric alteration. The alteration is most apparent in the intrusive rocks and in the more acidic rocks subjected to the highest metamorphic grades.

Plagioclase and potash feldspar display a broad range of alteration, from the most superficial (as in 9-3A) to total replacement (as in 13-4). The least altered feldspar occurs in a dacite pillow lava from the east end of Amlia, whereas the most altered feldspar (zeolitized) occurs in a massive basalt flow near the northwest end of the island. The most ubiquitous alterations of both plagioclase and potash feldspar are sericitization and kaolinitization. These alterations may be seen to a greater or lesser extent throughout the volcanic pile. Sericite(?) occurs most abundantly in some of the intrusive rocks of the island and in their volcanic host rocks. Kaolinitization of the feldspars is also generalized, but spottier in intensity than the sericitization. The basic trend, however, follows that of the sericite: more intense kaolinitization in the rocks of western and northern Amlia, more intense kaolinitization in certain intrusive rocks and their volcanic hosts, and more intense kaolinitization associated with rocks subjected to higher metamorphic grade. Zeolitization is frequently observed in the feldspars, particularly in the rocks from the north and west of Amlia. Zeolitization of the feldspars is generally much localized (i.e., to obvious zones of hydrothermal activity). The feldspars of the volcanic breccias are characteristically the most zeolitized. Zeolitization occurs first along fractures, then proceeds to included glass, and finally moves to total replacement. Smectitization, rare in the feldspars, sometimes accompanies zeolitization. This suggests hydration and ion-exchange by fluid migration through the rocks. The feldspars themselves are infrequently saussuritized, although epidote, pumpellyite, and prehnite are occasionally observed as alteration products. Here, higher grade metamorphism associated with magmatic intrusion and concomittent circulation of hydrothermal fluids rich in iron, calcium, magnesium, aluminum, silicon, and hydroxyl ions is apparent. Albitization was not observed in the Amlia rocks. The groundmass feldspars are generally too calcic, typically skeletal, and retain their twinned forms. Also, temperatures of metamorphism appear to be too low to generate secondary albite.

The rocks of Amlia Island were highly glassy. The greatest spectrum of alteration is to be found in the glasses. Devitrification is usually total in all the rocks. There are a few curiously-spaced exceptions! The glasses are most often altered to zeolites and smectites. In certain instances, however, the metamorphic grade was higher. Heat and migrating hydrothermal fluids produced less common phases from the glasses such as biotite(?), celadonite, chlorite, hematite, magnetite(?), and pumpellyite. In one such intensely altered rhyolite flow from near Cape Idalug on Amlia's north central coast (sample 11-6C), as much as fifty percent of the alteration is bright green celadonite. Associated alteration minerals (quartz, goethite, manganic oxide(?), and sericite(?) lead to the conclusion that this host rock had been hydrothermally altered by deuteric fluids rich in potassium, iron, magnesium, aluminum, silicon, and hydroxyl ions. Not far away, at Chalugas Bay, the most intense magnesian alteration of glass occurs (sample 11-4A). Here, in a massive basalt flow rock, the groundmass glass is totally converted to spherulitic magnesian chlorite and minor analcite. A striking example of propylitization, this rock displays phases almost totally altered to other minerals. In this instance, perhaps another source of fluids and metamorphism brought in abundant magnesium, aluminum, silicon, and hydroxyl ions, accompanied by smaller amounts of oxygen, carbonate, iron and sodium ions.

That the rocks of Amlia Island were metamorphosed hydrothermally by

exhalatives of varying compositions and at various times from some nearby magmatic source or sources seems without question. Direct evidence of this is seen again and again in the thin sections. Veinlets bearing secondary deposits of the same mineral phases seen in the adjacent host rocks are commonplace in the rocks of Amlia Island. Zeolites, smectites, quartz, and calcite are the most common vein-filling phases. Less frequently seen are hematite, goethite (may have originally been sulphides), manganic oxide(?) (may have originally been carbonate phases), kaolinite, prehnite, pumpellyite, and epidote. Other processes, such as seawater alteration of pillow lavas, may have had a part in the alteration of the original phases, but a notable example of relatively unaltered glassy selvage from a dacite pillow lava sampled near East Base on the northeast end of Amlia shows but little alteration other than the zeolite and iron-oxide-bearing veinlets that crosscut it. Even the orthopyroxenes here are remarkably fresh. Zeolite- and smectite-rich aureoles spread out into the fresh host rock away from the veinlets. Surely hydrothermal activity must have been a very important agency of metamorphism on Amlia. Deuteric deposits in the gas vesicles of the rocks reflect hydrothermal activity as well: the phases filling or lining the vesicles usually reflect the phases found in the hydrothermal veinlets cutting their hosts (exceptions: epidote, kaolinite, hematite, manganese oxide(?), and goethite). It must be remembered that many factors and variables affect metasomatism in rocks and that many complex changes can take place over long periods of time. Large uncertainties as to the relationships that original rock compositions, porosity, and permeability, bear to temperatures, pressures, and ion concentrations in fluids through space and time greatly complicate the interpretation of metamorphosed rocks. It is also difficult to make definitive interpretations or to draw firm conclusions mainly from the study of thin sections.

SUMMARY AND CONCLUSIONS

The samples selected for this study are representative of a series of intercalated volcanic and volcanogenic sedimentary rocks, and their associated intrusive rocks that make up Amlia Island and probably large parts of the more extensive Aleutian Ridge. The volcanic rocks range in composition from basalt through rhyolite and the intrusive rocks are of similar compositions through dacite. The modal mineralogies of the rocks are remarkably similar, varying mainly in the proportions of the mineral phases rather than in mineralogic differences. Primary mineral phases present in nearly all the rocks include plagioclase, clinopyroxene, orthopyroxene, and ores. The ubiquitous presence of orthopyroxene and the general poverty of olivine in the basic rock is curious. Plagioclase is highly calcic, becoming more sodic in the acidic rocks. Few other striking changes are apparent. These data suggest a single magmatic source for the Amlia igneous rocks, with compositional variation due to localized assimilation of materials from the host environment and differentiation by fractional crystallization. This implies a stability of the Aleutian plate tectonic regime during the period of construction of, at least, the Amlia portion of the Aleutian Ridge (Vallier and others, 1981).

Metamorphism of the Amlia rocks is generally propylitic, with alteration principally in the form of simple hydration, hydroxylation, and light-element ion-exchange. Smectitization and zeolitization are the principal agencies of alteration apparent in the rocks, followed by oxidation, sericitization, and silicification. Saussuritization and amphibolization are rare and

localized. Secondary minerals observed in thin section include actinolitic amphibole, analcite, biotite(?), calcite, celadonite, chlorite, chlorophaeite and other smectites, epidote, goethite, hematite, kaolinite, leucoxene, manganic oxide(?), prehnite, pumpellyite, quartz, sericite(?), natrolite and other zeolites.

Evidence of heating, fluid migration, ion diffusion, and ion exchange through the rocks of Amlia is apparent from the trend toward uniformity of low level oxidation, carbonation, ion enrichment and removal, and from hte abundance of cross-cutting zeolite, calcite, and quartz veinlets in the rocks. Abundant, localized enrichment with uncharacteristic suites of elements, such as potassium and iron, also indicates a hydrothermal origin for most of the metamorphic processes. Interpretation of the rocks of Amlia Island is made difficult by large uncertainties concerning variables such as original rock compositions, pH_2O, pCO_2, pH, porosity, permeability, temperature, and ions in introduced fluids. Working with little other than thin sections increases the difficulties and uncertainties.

ACKNOWLEDGMENTS

Special thanks are extended to T. Vallier, H. McLean, and J. Hein for access to their field samples, thin sections, X-ray data, and general information about Amlia Island geology. D. Clague provided expertise in generation of microprobe analyses. Also much appreciated were critical readings of the drafts of this manuscript by T. Vallier and D. Clague.

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